SCIENCE FOR CERAMIC PRODUCTION

UDC 666.642.3:666.3.032.62

MECHANIZATION OF MOLDING OF LARGE-SIZED POTTERY

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Translated from Steklo i Keramika, No. 10, pp. 9 – 11, October, 1999.

New technological parameters are developed for molding pottery on a semiautomatic production line. The labor-intensive process of molding large-sized pottery articles is mechanized. The technical, economical, and quality parameters are improved, the number of rejected pieces is decreased, and the efficiency is increased.

Plastic molding of large-sized ceramic products is a labor-consuming process. It is known that, of the total labor involved in producing flat ceramic articles, 16 – 22% is spent on molding, and for hollow articles this figure is even higher (including souring, setting, and attachment of parts).

Many domestic and foreign factories widely use integrated mechanized and automated lines for molding, setting, and drying of plates, cups, pots, etc.

The Gzhel' production company currently uses an FH-1 molding line (made by Turingie company) for molding large-sized ceramic pots with a capacity over 2 liters. The line output is 200 – 260 pieces/hour. The molding line FH-1 (Fig. 1) consists of: two molding machines *1* with molding rolls equipped with automatic manipulators *2* for feeding gypsum molds *3* to the molding machines and to the conveyor of the tunnel drier; a drier *4* with directed heat flow; an electric drive and a fan *5*.

Plastic molding based on plastic deformation of a ceramic mixture under the effect of external forces (pressure of the roll or the template) requires optimum choice of the mixture moisture and plasticity. A necessary condition for plastic molding is the use of sufficiently viscous mixtures, in which the sum of the internal cohesive forces exceeds the total force of adhesion to the working surface of the molding equipment, and the internal friction coefficient exceeds the external friction coefficient [1].

The development of a new majolica mixture composition provided for improvement of molding properties which largely depend on the mixture moisture. The recommended batch composition for majolica mixture was as follows (%): 65 low-melting clay from the Gzhel'skii deposit, 5 clay from the Chasov'-Yarskii deposit, 25 nepheline sienite; 5 quartz sand. The ceramic properties of the majolica mixture intended for making ceramic pots on the FH-1 line are given below:

Residue of sieve No. 0056 (10,000 holes/cm^2), %	2.2 – 2.6
Plasticity	medium plasticity (2.4)
Drying sensitivity coefficient	low sensitivity (0.98)
Molding moisture, %	22 – 25
Sintering interval, °C	980 – 1060
Shrinkage, %:	
air shrinkage	6 – 7
firing shrinkage (1020°C)	3.5
Water absorption (1020°C)	10.8 – 11.1
Bending strength of fired articles (1020°C), Pa	37

Vacuum treatment of the mixture is essential in plastic molding. The air adsorbed on the surface of clay particles can be removed to a maximum possible extent by deep vacuum treatment, whose significance mostly depends on the mineralogical composition and dispersion of clay. This air impedes water wetting of clay particles and prevents uniform

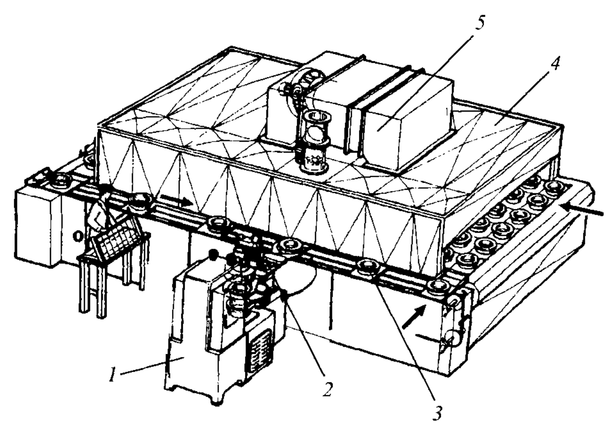

Fig. 1. Semi-automatic line FH-1 for molding large-sized pots.

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TABLE 1

Evaluation, 10^{-3} Pa	Bending strength of articles in air-dry state (MPa) for number of kneadings		
	1	2	3
9.0	3.82	4.03	4.12
9.9	4.01	4.48	4.85

TABLE 2

Parameter	Mixture moisture, %				
	21.0 – 22.0	23.0	23.5	24.0	24.5
Rotational speed, $\min^{-1}$:					
of spindle	300	300	250	250	200
of molding roll	170	160	135	125	100

compaction of the mixture, which results in decreased strength of articles and formation of microcracks in the course of drying and firing.

It is known that as the mechanical strength of mixtures increases, the speed of molding and, accordingly, the efficiency increases as well. The study in [2] established the increase in mechanical strength of a porcelain mixture after deep vacuum treatment. The present study concentrates on variations in the mechanical strength of the majolica mixture under different conditions of vacuum treatment.

The optimum rarefaction in the vacuum chamber of the molding press for vacuum treatment of the majolica mixture was determined experimentally by varying the vacuum level from 9.0×10^3 to 9.9×10^3 Pa (Table 1). The results of the experiment indicated that the mechanical strength of the mixtures varies under changes in vacuum; for example, the strength of the mixture increases insignificantly with increasing rarefaction in the vacuum chamber and increasing number of kneadings. A maximum mechanical strength equal to 4.85 MPa was attained in a mixture subjected to vacuum treatment at a rarefaction of 9.9×10^3 Pa and triple kneading.

The moisture of a mixture is of great importance for plastic molding, along with vacuum treatment. The moisture should ensure that the mixture is easily moldable and at the same time would not stick to the molding rolls. In this case a minimum amount of electricity is consumed on compression and molding of the mixture, and the molded articles have the required strength.

The use of ceramic mixtures which provide for increased strength of material has significant advantages. In this way it becomes possible to mold thin-walled ceramic articles which due to increased strength can have low deformation capacity.

The necessary moisture level for majolica mixtures is selected experimentally, since the moisture of a mixture depends on the rolling force produced by the molding roll. Mixtures with moisture of 20, 21, 22, 23, 24, and 25% were tested in making ceramic articles. As 1.0 – 1.5-liter flower pots were molded on an automated line with a molding roll, it was found that the majolica mixture with 20% moisture is not properly flattened inside the gypsum mold, and when the moisture is over 22%, the mixture sticks to the roll. The optimum moisture for this type of pottery products is 21 – 22%. For this level of moisture, well-molded pots were obtained.

The moisture determined for the above experiment (21 – 22%) was found to be unsuitable for pots holding 1.5 – 2.5 liters, due to the absence of the flattening effect inside the gypsum mold. Accordingly, the moisture was increased to 24%. However, on attaining 24% moisture, the mixture stuck to the molding roll. The optimum moisture of the mixture in this case was 22.0 – 23.5%.

Molding of large-sized articles (pots holding over 2.5 liter) was performed with a mixture moisture of 23 – 25%. When the moisture of the mixture was 23% or less, a defect caused by insufficient molding was observed in the products; whereas when the moisture level was above 25%, another defect ("licking") was frequently observed on the internal side of the molded articles. The moisture level was selected based on the rejected molded articles. The optimum moisture for this category of large-sized articles was 23.5 – 25.0%.

Consequently, the larger the volume of plastically molded articles, the higher the level of moisture required (although within a specific interval which provides for high-quality articles). Unbalanced moisture of the mixture affects the quality of the molded products.

It is known from experience in porcelain and faience production that correct selection of the rotational speed of the spindle and the molding roll has a great effect on the product quality. The optimal peripheral velocity at different points of the article which are the most remote from the rotational axis in molding should not exceed 5 m/sec for plates and 4.15 m/sec for saucers [1].

Considering the lack of experience in molding large-sized pottery articles on an automated machine with a molding roller, the correlation between the rotational speeds of the spindle and the roller was determined experimentally. The rotational speed of the roller and the spindle was determined in connection with the moisture of the mixture. The optimum rotational speed in molding was selected based on the presence of defects in the molded articles.

As the result of the experiments, it was found that the rotational speed of the spindle decreases as the moisture of the mixture increases and, consequently, the rotational speed of the molding roll decreases. The experiments revealed an increase in the ratio of the rotational speeds of the spindle and the roll as moisture increased (Table 2) and the necessity of increasing the spindle rotational speed when the moisture of the mixture is low. The rotational speeds of the spindle and the molding roll given in Table 2 largely depend on the size of the article.

The experimental studies revealed the effect of gypsum molds on the quality of molded articles, and their low turn-

over in molding on the automated machine with the molding roll.

Gypsum molds intended for service on an FH-1 semi-automatic production line should have the following specifications;

Porosity, %	Around 60
Prevailing diameter of pores, μm	1 – 4
Water absorption, %	30 – 40
Bending strength, Pa	24 – 39
Service life	40 – 50
Moisture of mold in molding, %	Not more than 5

Thus, the installation of the FH-1 production line at the Gzhel' company resulted in a revision of the traditional pottery-molding technology: a new multicomponent majolica mixture was developed; new technological parameters for plastic molding were determined (moisture of mixture, rotational speed of the spindle and the roll, specifications of gypsum molds). All this made it possible to mechanize the labor-consuming process of molding large-sized pottery, improve its technical and quality parameters, decrease the number of pieces rejected in molding and drying of the intermediate products, reduce production cost, and increase efficiency.

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